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Metropolitan Sanitary District of Greater Chicago, IL

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16. ABSTRACT

The objective was to demonstrate the fertilizer and soil conditioning qualities of liquid digested sewage sludge in renovation of a landfill consisting of ash, concrete, metals, glass, etc. Liquid digested sludge applied in furrows at a rate of 50 metric tons per hectare in 1970, after having been applied at a rate of 85.8 metric tons per hectare in 1969, increased corn yields significantly. Wheat yields on sludge-treated plots yielded 2822 and 2957 kg/Ha in 1970 and 1972, respectively.

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by

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution, and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for preventing, treating, and managing wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for preserving and treating public drinking water supplies, and for minimizing the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research--a most vital communications link between the researcher and the user community.

This report describes an approach for using sludges from biological wastewater treatment plants and indicates the potential beneficial effect of the sludge on unproductive land at a burned landfill site.

Francis T. Mayo
Director
Municipal Environmental Research
Laboratory

ABSTRACT

The Calumet land reclamation project developed design criteria for applying liquid fertilizer (sludge) to land and demonstrated the beneficial and economic use of it in raising crops.

The scope of the project included developing a pipeline system to transport liquid fertilizer to the application site, determining yields, analyzing plant tissue of the crops grown, observing the soil changes effected by the liquid fertilizer application, and monitoring the ground and surface water of the application site.

The pipeline was built and transported liquid fertilizer from the lagoons to the application site. The application of liquid fertilizer increased the yields of wheat and corn, increased the concentration of plant nutrients in the plant tissue, and effected organic improvements in the soil. Analysis of the leachate from the piezometers showed that groundwater constituents fluctuated, partly because surface water seeped through the perforations in the piezometers at the soil surface. This pollution did not reach the groundwater aquifer sampled from a deep well constructed of solid wall pipe.

This report was submitted in fulfillment of Grant No. 11010 DPW by the Metropolitan Sanitary District of Greater Chicago under the partial sponsorship of the Environmental Protection Agency. The report covers the period June 1, 1969 to December 31, 1972, and work was completed as of December 31, 1972.

CONTENTS

Foreword. iii
Abstract. iv
Figures vi
Tables. vii
Metric Conversion Factors viii

1. Introduction. 1
2. Summary and Conclusions 2
3. Site Description. 5
4. Transportation, Distribution, and Application Methods . . 10
5. Liquid Fertilizer Application 17
6. Crop Production 23
7. Farm Equipment Used on the Calumet Project. 28
8. Soil, Plant, and Water Responses. 39

References. 50

FIGURES

Number		Page
1	Aerial view of the Calumet land reclamation site	6
2	Plot diagram 1969, 1970, and 1971	7
3	Locations of borings that determined the depth and composition of the fill	8
4	Thirty-horsepower submersible pump	11
5	Raft and submersible pump	12
6	Mechanical agitator	12
7	Action of the air lance	13
8	Air compressor for air lance	14
9	Fifty-horsepower booster pump	14
10	Aluminum pipe connected to conveyance system under the railroad tracks	15
11	Aluminum pipe and vinyl hose	16
12	Plot diagram, August 1971	22
13	Harvesting wheat for yeild determination	23
14	Corn fertilized with liquid fertilizer	24
15	Corn not fertilized with liquid fertilizer	25
16	Wheat fertilized with liquid fertilizer	26
17	Soil surface, Calumet land reclamation	27
18	Tractor used on the Calumet land reclamation project	28
19	Landscape rake	29
20	Moldboard plow	30
21	Lister	31
22	Four-row corn planter	32
23	Sprayer	32
24	Twelve-foot disk harrow	33
25	Heavy duty disk harrow	34
26	Berm disk	34
27	Ditcher	35
28	Grain drill	36
29	Sickle bar mower	36
30	Rotary mower	37
31	Monitoring well, Calumet Farm	48
32	Schematic drawing of monitoring well, Calumet Farm	49

TABLES

Number		Page
1	Data from 27 borings on the Calumet land reclamation site	9
2	Liquid fertilizer applied to land at the Calumet treatment plant during 1969	17
3	Liquid fertilizer applications for 1970	18
4	Liquid fertilizer applications for 1971	19
5	Liquid fertilizer applied to land at the Calumet Farm during 1969, 1970, and 1971	20
6	Liquid fertilizer applications for 1972	21
7	Analysis of liquid fertilizer applied at Calumet Farm from 1969 to 1972	40
8	Summary of soil characteristics (0-6" depth) of Plot A, Calumet Farm, before and three dates after the application of liquid fertilizer	41
9	Chemical content of winter wheat tissue from a liquid-fertilizer-treated landfill at the Calumet Farm	42
10	Calumet land reclamation site mean chemical concentrations (ppm) for leachate collected monthly from three piezometers during May through December, 1969	43
11	Calumet sanitary landfill site mean chemical concentrations for leachate collected weekly from three piezometers from September through December 1970	44
12	Calumet sanitary landfill site mean chemical concentration for leachate collected weekly from three piezometers for the year 1971	45
13	Calumet sanitary landfill site mean chemical concentrations for leachate collected monthly from January 25, 1971 to June 23, 1972, from three piezometers and a monitoring well	46
14	Calumet sanitary landfill site annual mean chemical concentrations for leachate from 1969 to 1971	47

METRIC CONVERSION FACTORS

Length:

1 inch = 25.4 millimeter (mm)
= 2.54 centimeter (cm)

1 foot = 30.48 centimeter (cm)
= 0.3048 meter (m)

Area:

1 acre = 0.405 hectare (ha)

Volume:

1 gallon = 3.785 liter (l)

Pressure:

1 pound per square inch = 0.07031 kilogram per square centimeter (kg/cm^2)

Rate:

1000 gallons/acre = 3.785 kiloliter (kl)/acre
1 ton/acre = 2.240 ton (metric)/hectare (ha)
1 pound/acre = 1.12 kilogram (kg)/hectare (ha)

Mass:

1 ton (English) = 0.9072 ton (metric)
1 pound = 0.454 kilogram (kg)

SECTION 1

INTRODUCTION

The Metropolitan Sanitary District of Greater Chicago has adopted a policy of applying liquid sludge, the product of the wastewater treatment process, to land. This product is called liquid fertilizer in this report. The District employed Harza Engineering, a consulting firm, to seek land for liquid fertilizer application and investigate methods for liquid fertilizer transportation and application. These feasibility studies by Harza represent the first phase of what became known as the "solids-on-land" program. The solids-on-land program has resulted in the District's adoption of several self-imposed stipulations; that it be economical; that it use the organic matter produced in the wastewater treatment process for a beneficial purpose; and that it solve the problem into perpetuity.

The objectives of the project were: (1) to develop design criteria for applying sludge to land, and (2) to demonstrate the beneficial and economical use of liquid fertilizer to raise crops.

During 1968, liquid fertilizer production by the Calumet wastewater treatment plant necessitated more storage capacity or the removal of liquid fertilizer from the existing lagoons. Pursuing the land reclamation concept, the District purchased and started preparation of an adjacent landfill site for liquid site preparation and started construction of a fertilizer conveyance system from the plant and from the lagoons to the application site. By mid 1970, the District completed the liquid fertilizer conveyance system.

SECTION 2

SUMMARY AND CONCLUSIONS

The information obtained from the Calumet project proved invaluable for the Fulton County Land Reclamation Project.

Here is what the Sanitary District learned and how it applied this knowledge in Fulton County.

1. To determine whether liquid fertilizer spread on soil will pollute the water, it is essential to measure water quality before and during liquid fertilizer application. At Calumet, liquid fertilizer applications and water quality determinations were started about the same time. In Fulton County water quality determinations were started 18 months before application.

2. The three piezometers that extend from the soil surface to the depth of fill are made of perforated pipe. The Calumet experience showed that solid wall pipe must be used for piezometers and monitoring wells. During liquid fertilizer applicaton and rainfall water containing solids can enter a perforated pipe and pollute the well. The well at the Calumet farm and the 17 monitoring wells on the Fulton County Project are constructed of solid wall pipe to within 10 feet of the bottom of the well.

3. At Calumet, a small concrete cap poured on the soil surface surrounding the piezometer inhibited, but did not eliminate surface runoff into the piezometers. To reduce surface runoff effects at Fulton County, a concrete base four feet by four feet surrounds the monitoring wells.

4. The berms constructed of fly ash and debris failed to contain liquid fertilizer because they degraded from the effects of rain, freezing and thawing and liquid fertilizer application. Mending the berms with clay showed that they would contain the liquid fertilizer, hence clay berms were constructed in Fulton County.

5. Rock and trash removal from the soil is essential. Rocks interfered with the use of many farm machines, notably listers and plows. In Fulton County on land intended for crop production, rock removal follows chisel plowing but precedes crop planting.

6. The Calumet farm experience indicates that herbicides will control weeds when liquid fertilizer is applied. Water, either as rain or irrigation, activates most herbicides, but too much water leaches the herbicide below the root zone making it ineffective.

7. The project demonstrated that the application of liquid fertilizer to unproductive land, like incinerated fly ash, will allow the growing of crops. Other contemporary demonstration projects showed that the application of liquid fertilizer permitted crop growth on strip mine spoils, alkaline glass factory wastes, and unproductive clay soils. Hence, growing crops on this incinerated fly ash showed the efficacy of applying liquid fertilizer to almost any soil material to enhance crop production.

8. Attempting to distribute liquid fertilizer by the ridge and furrow method showed that land must have a smooth surface and slope to prevent ponding. The land also must be free of rocks and debris in order to form ridges and furrows with a lister. Because of these difficulties, spray irrigation will be used in Fulton County.

9. The Calumet project showed that a completely closed drainage system on an agricultural field is possible. The drainage system on the Calumet project recycled all runoff to the lagoons while the drainage system on the Fulton County project impounds the water for monitoring before it is released to the stream or recycled onto the field.

10. The project demonstrated the limitations of submersible pumps for removing the liquid fertilizer from lagoons. Twenty-horse-power pumps had too little power and repeatedly plugged and burned out. The maximum solids concentration that could be pumped was about 2.5%. A 30-horsepower pump removed up to 175,000 gallons of liquid fertilizer containing 6% solids per 8-hour day. However, when the fertilizer contained more than 6% solids, the pump overheated, causing the thermal switch to stop the pump. With these experiences and considering the volume to be pumped, a dredge was purchased for the Fulton County project.

11. At Calumet, the liquid fertilizer required agitation to keep it flowing into the pump inlet. Mechanical agitation and agitation by air lances fluidized the fertilizer for pumping. Without agitation, the pump overheated and burned out or shut off. The District provided a dredge for the Fulton County project to remove liquid fertilizer from the holding basins. This dredge had a rotating head, positioned immediately in front of the pump inlet. to fluidize the fertilizer.

12. Agronomic improvements in the landfill from 3 years of liquid fertilizer application are:

    a. A threefold increase in the cation exchange capacity

    b. A twofold increase in the concentration of available P, but a reduction in the concentration of total P.

    c. An increase in the concentrations of Ca, Cu, K, Mg, Mn, S and Zn.

    d. A decrease in the concentrations of Al, Cr, Na, Ni.

13. The data also show that 3 years of liquid fertilizer application increased the Pb concentration of the landfill, but the electrical conductivity fluctuated.

14. Application of liquid fertilizer increased the plant nutrient content of the leaf tissue of winter wheat. The Zn content was higher than required for maximum crop production, but was not at a toxic level.

15. Analysis of the leachate from the three piezometers for 4 years shows that:

    a. the concentrations of all forms of N fluctuated,

    b. the concentrations of Cd, Cr, Mg and Mn fluctuated,

    c. the concentration of Fe increased,

    d. the concentrations of Ca, Cu, Hg, K, Na, Ni decreased,

    e. conductivity decreased, and

    f. the fecal coliform count fluctuated.

SECTION 3

SITE DESCRIPTION

Figure 1 shows an aerial view of the Calumet Land Reclamation site. This site is west of and adjacent to the Calumet Expressway. It extends from 130th Street north to the bend in the Calumet Expressway. The railroad tracks are the west border. The lagoons and the Calumet plant are west of the application site and west of the railroad. This site is located in the south part of Chicago about four miles west of the Indiana border.

Figure 2 shows the plot design of the entire site. Six plots, A thru F, comprised the south end while plots numbered 1 thru 20 comprised the north end. The area between plots A thru F and plots 1 thru 20 consists of hills and trees and is unsuitable for liquid fertilizer application.

Plots A, B, C, D, E, and F contain 5.0, 4.93, 6.19, 1.20, 0.90, and 1.22 acres, respectively. Plots 1 thru 9 contain 1.55 acres each, plots 11 thru 15 contain 1.1 acres each, plots 16 thru 20 contain 1.54 acres each with the exception of plots 17 and 18 which contain 1.2 acres and 1.4 acres, respectively. Plot 10 contained the stones used for field roads. The triangular plot south of plot 20 is a check plot. Berms, about 12" high, formed the borders of the plots.

A contract completed during 1969 prepared the Calumet farm. The contractor removed debris, leveled the site, and created a slope of 0.25% from west to east which permitted the application of liquid fertilizer by ridge and furrow. The liquid fertilizer was discharged into furrows on the west side of the field and slowly flowed to the east side of the field.

The ditches that surrounded the entire site collected and recycled runoff to the treatment plant. Thus the entire application site was self-contained.

The matrix at the surface of this former dump site is fly ash, an incinerated material incapable of growing crops. Table 1 shows the depth of the fill as indicated by 27 borings, while Figure 3 shows the location of these borings used to determine the depth and composition of the fill. Completion of these borings preceded site preparation.

Figure 1. Aerial view of the Calumet land reclamation site.

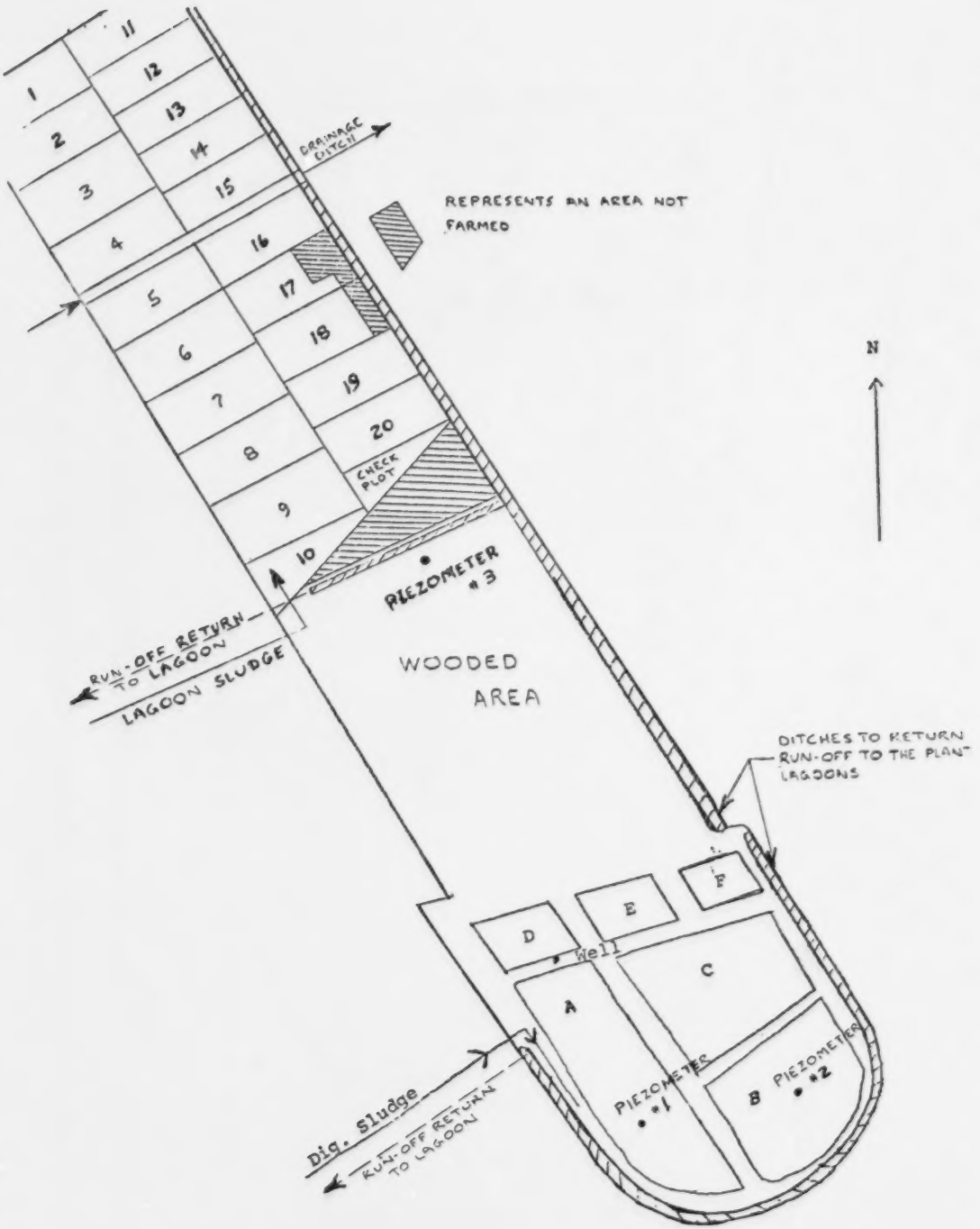

Figure 2. Plot diagram 1969, 1970 and 1971.

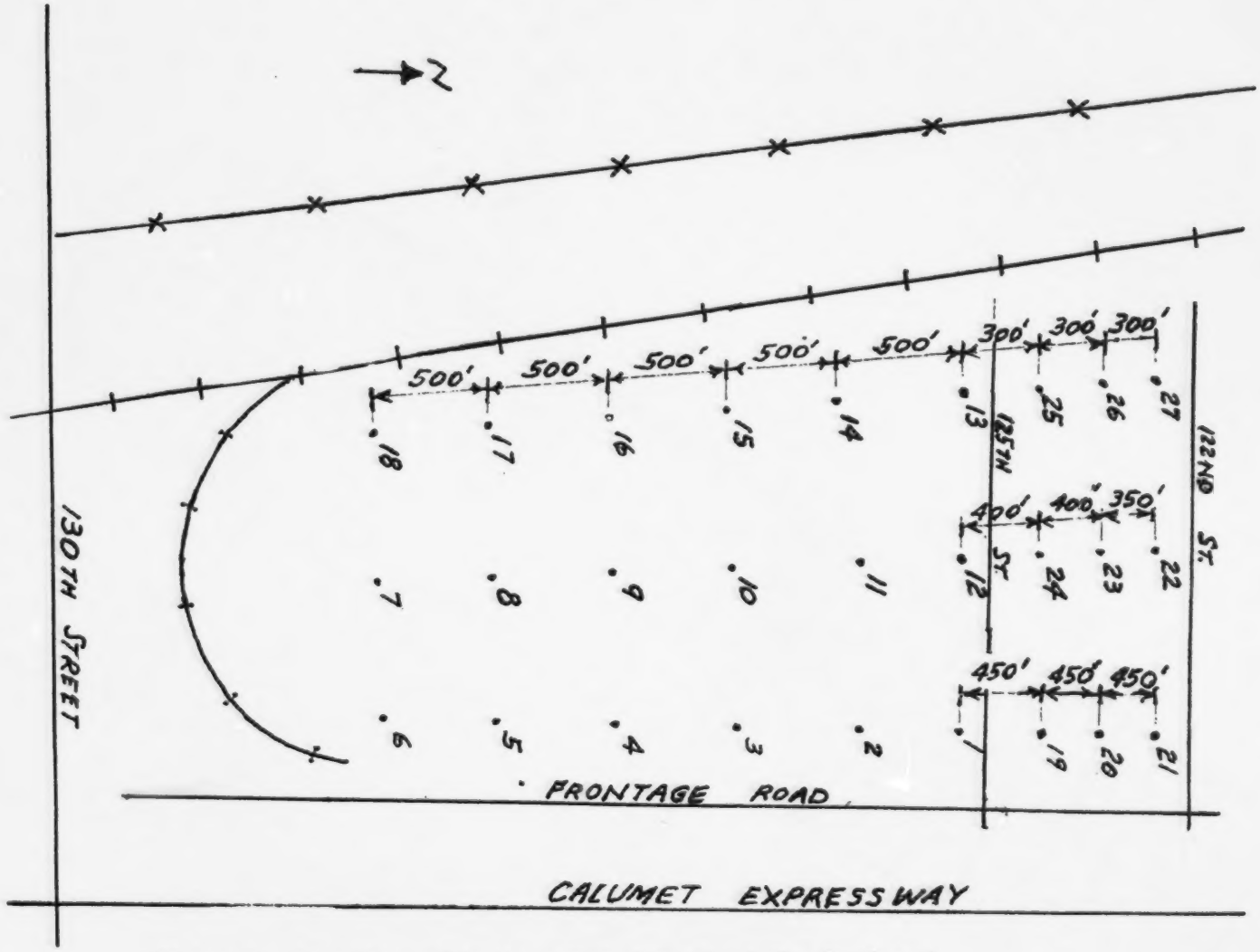

Figure 3. Locations of borings that determined the depth and composition of the fill.

TABLE 1. DATA FROM 27 BORINGS ON THE CALUMET LAND RECLAMATION SITE

Boring No.	Depth of Fill (Feet)	Total Depth of Boring (Feet)	Water Level Readings While Sampling (Feet)	Water Level Readings After Boring (Feet)
1	11.0*	17.0	16.0	15.0
2	9.5	17.0	9.0	9.0
3	9.0	17.0	9.0	9.0
4	3.5	12.0	3.0	3.0
5	3.5	12.0	3.0	3.0
6	4.0	12.0	3.0	2.0
7	9.5	17.0	6.0	5.5
8	9.0	17.0	7.0	6.5
9	9.5	17.0	8.0	8.0
10	17.0	22.0	dry hole	
11	16.5	22.0	15.0	13.0
12	17.0	22.0	14.0	14.0
13	13.0	17.0†	dry hole	
14	13.0	17.0†	dry hole	
15	3.5	12.0	dry hole	
16	3.5	12.0	dry hole	
17	9.5	12.0	dry hole	
18	9.0	17.0	dry hole	
19	5.0*	16.0ǂ	4.8	3.0
20	8.5*	15.0	6.5	dry
21	9.0*	15.0	7.0	6.5
22	8.0*	15.0	dry hole	
23	8.0*	15.0	5.0	4.5
24	8.0	15.0	dry hole	
25	7.5*	15.0	dry hole	
26	7.5*	15.0	dry hole	
27	4.0*	10.0	dry hole	

* Indicates the fill is basically a clay material; all other fills are made up of cinders, wood, and glass.

† Indicates the soil from the base of the fill to the bottom of the boring is a sandy silt; all others are silty clay.

ǂ Indicates a 3-foot layer of topsoil and black organic clay underneath the fill.

SECTION 4

TRANSPORTATION, DISTRIBUTION, AND APPLICATION METHODS USED TO CONVEY AND APPLY LIQUID FERTILIZER

Two 75-hp pumps moved the liquid fertilizer from the digesters to the lagoons, or to the south end of the farm for land application, or to a 50-hp booster pump for land application at the north end of the farm. The 75-hp pump capacity ranged from 1,400 to 1,800 gpm (one operating and one standby).

At the lagoons, a 20-hp pump removed the liquid fertilizer from the lagoon to the booster pump for conveyance and application to the field. This pump was inadequate for continuous pumping. It did effectively pump liquid fertilizer from the lagoon when the solids concentration was less than 2.5 percent, but as the solids content increased pump reliability decreased. During 1971, this pump was replaced because the motor burned out. The new 20-hp submersible pump also required dilution water and constant agitation near the pump inlet to maintain solids content below 2.5 percent. During the Spring of 1972, a new 30-hp submersible pump replaced the 20-hp submersible pump. This 30-hp submersible pump was capable of pumping 175,000 gallons per day of liquid fertilizer containing six percent solids. However, higher solids concentrations caused the thermal switch to stop the motor. Two hours of cooling were required before the motor could be restarted. Figure 4 shows the pump.

The raft shown in Figure 5, designed and built especially for this project, supported the submersible pump. A winch was used to raise and lower the pump. Air lances and mechanical agitators were used to break up the large solids (rags and stringy materials) at the pump inlet. The raft consisted of a steel grate mounted on pontoons to permit floating in the lagoon. A catwalk provided access from shore to this raft. The submersible pump was raised or lowered through a hole in the center of the steel grate.

Two methods of agitation enabled the submersible pump to remove liquid fertilizer from the lagoons. Figure 6 shows a mechanical agitator which was a 3-blade, 12-inch propeller on the end of a 3-foot shaft connected to an electric motor. It operates in the vertical position at the same depth as the submersible pump. Mounting this agitator on hinges allowed raising it to the horizontal position for cleaning.

The other agitation system used was the air lance. Figure 7 shows the bubbling caused by injecting air into the liquid fertilizer on either side of the raft. The air lance was simply a 1-inch pipe, 9 feet long, connected to an air source. The open end of the pipe was submerged to the same depth as the inlet of the submersible pump and fluidized the liquid fertilizer for pumping. The air lance was the more effective method of agitation mainly because of its mobility.

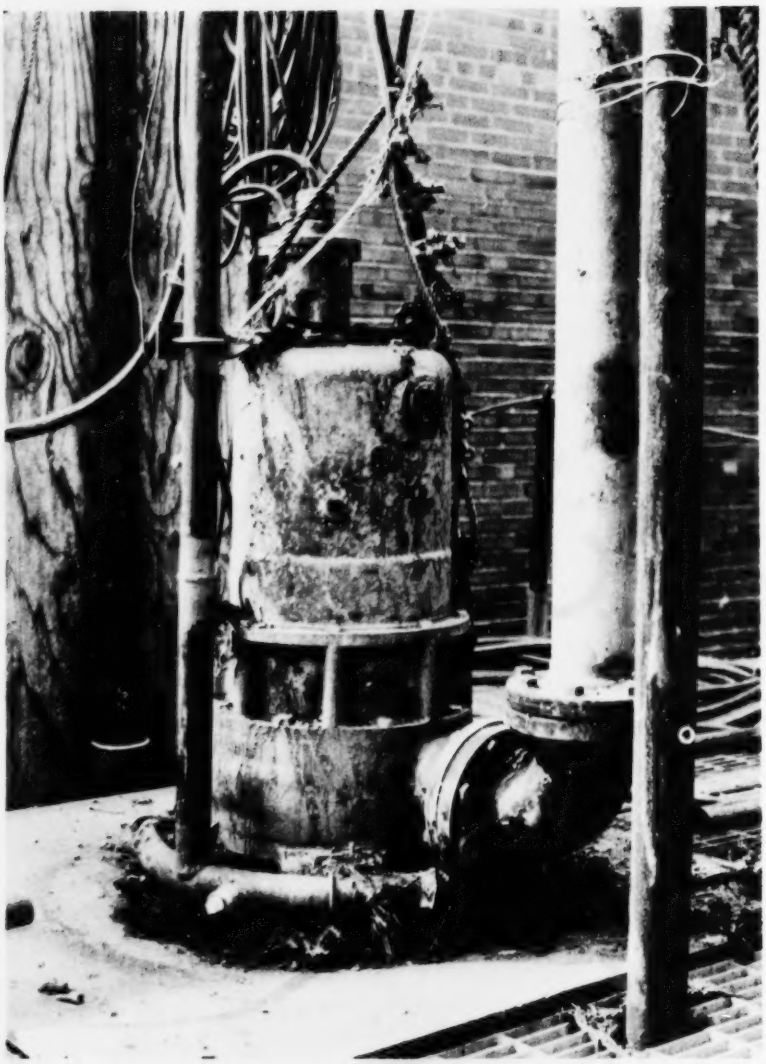

Figure 4. Thirty-horsepower submersible pump.

Figure 8 shows the air compressor which delivered the 15 pounds of pressure to the two air lances.

Figure 9 shows the 50-hp booster pump. This pump, mounted on a concrete base, transported the fertilizer from the discharge pipe of the digesters to the north end of the farm. It also transported the liquid fertilizer from the submersible pump in the lagoon to either end of the farm. The performance of this pump was more than adequate.

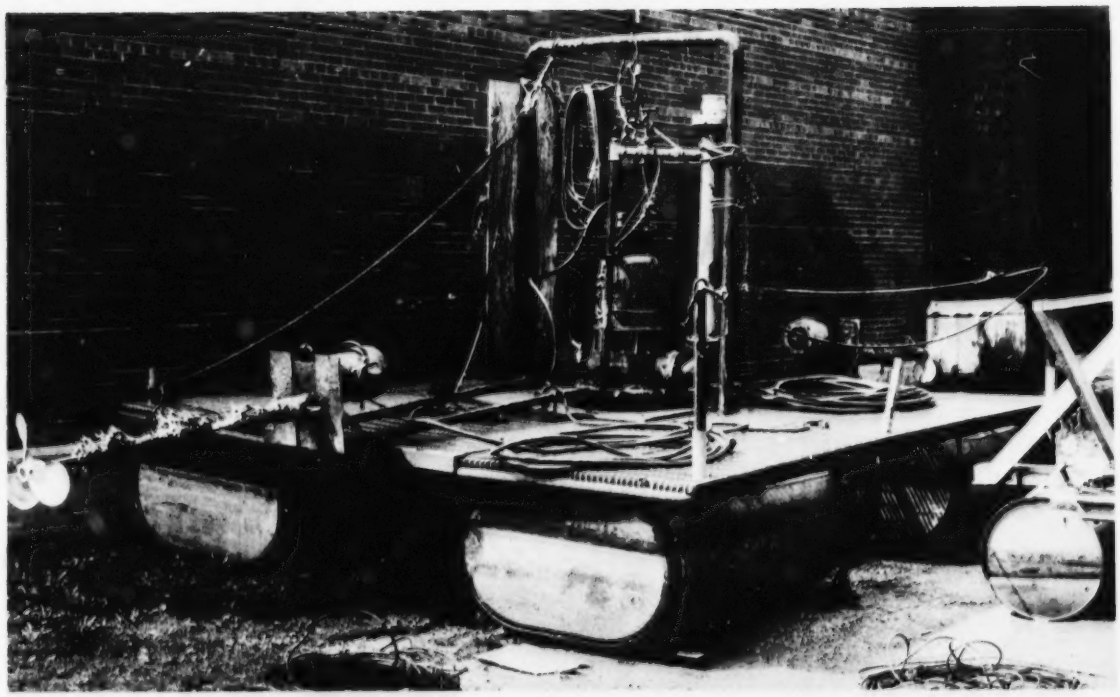

Figure 5. Raft and submersible pump.

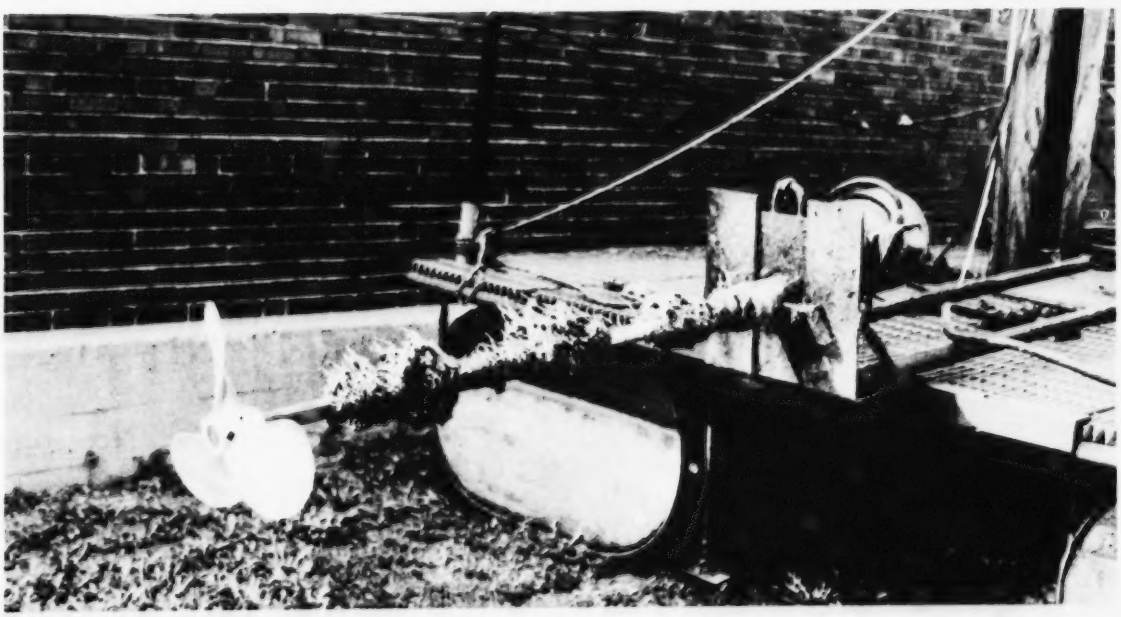

Figure 6. Mechanical agitator.

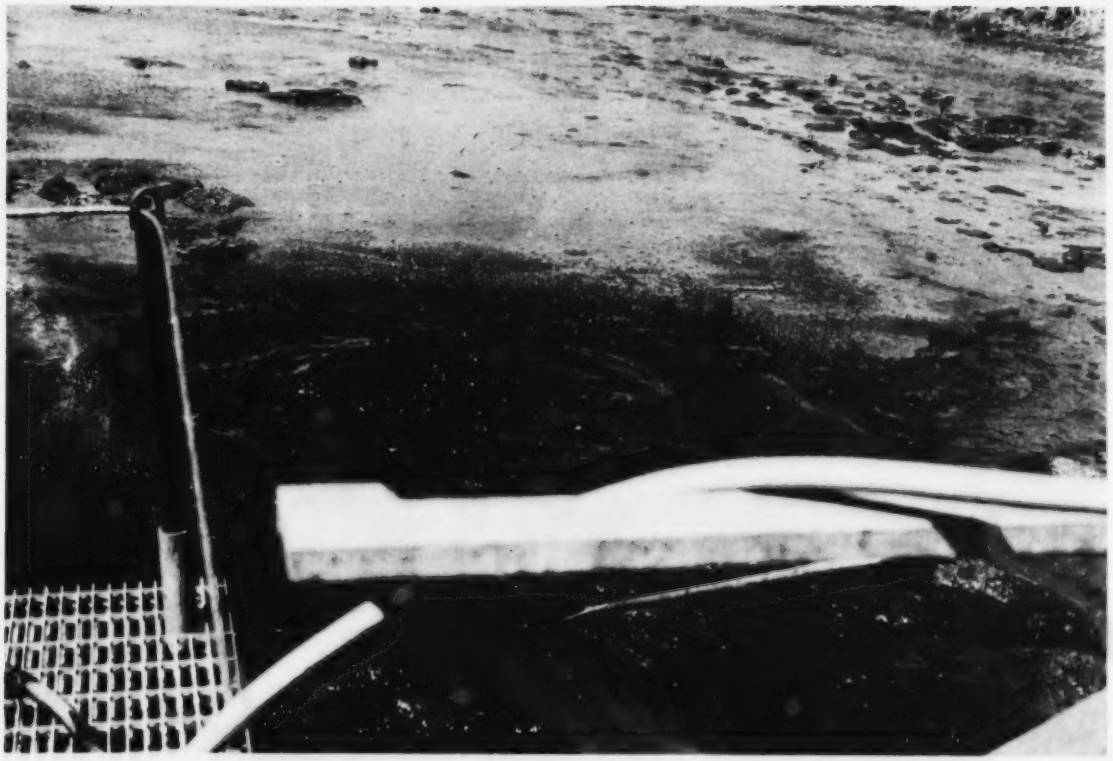

Figure 7. Action of the air lance.

The conveyance system moved the liquid fertilizer from the digesters, or the lagoons, to the point of land application. The submersible pump below the raft, or the pumps at the digesters, moved the liquid fertilizer through a 6-inch pipe to the booster pump which then pumped it through a 6-inch pipe beneath the railroad tracks to the farm. A 6-inch aluminum pipe used with a 4-inch soft vinyl hose at the discharge end delivered the liquid fertilizer for land application. Figure 10 shows aluminum pipe connected to the pipe under the railroad tracks. Figure 11 shows the aluminum pipe and vinyl hose that delivered the liquid fertilizer for land application.

The liquid fertilizer application methods tried were ridge and furrow, rain guns, and flooding. The ridge and furrow failed for two reasons. First, the land surface was not uniformly level but had relief that caused ponding in the furrows. Second, the lister forming the ridges and furrows could not function because of the debris. Rain guns proved impractical because they were stationary. Frequent movement of the rain gun and the pipes was impractical. The District could not use moveable rain guns because the broken glass, rods, etc., in the debris would cut or puncture the hose that must follow the rain guns. Finally, the pumps available created only 46 pounds of nozzle pressure while 80 pounds is the absolute minimum for satisfactory operation.

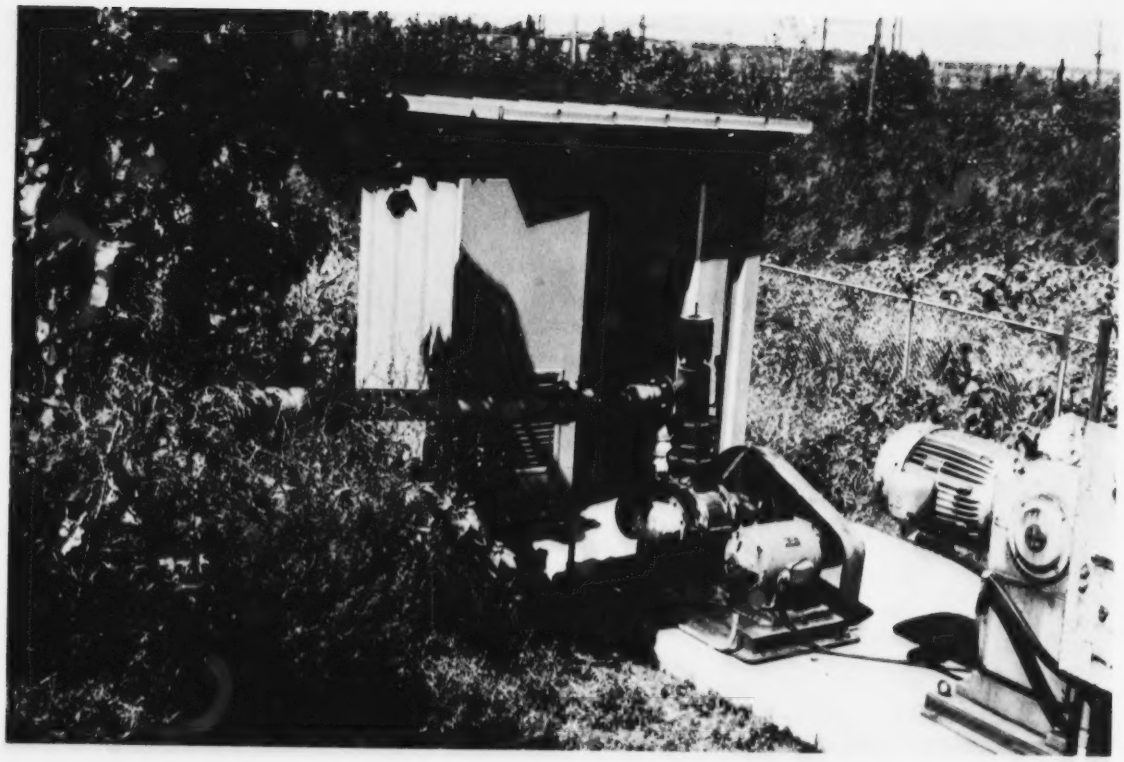

Figure 8. Air compressor for air lances.

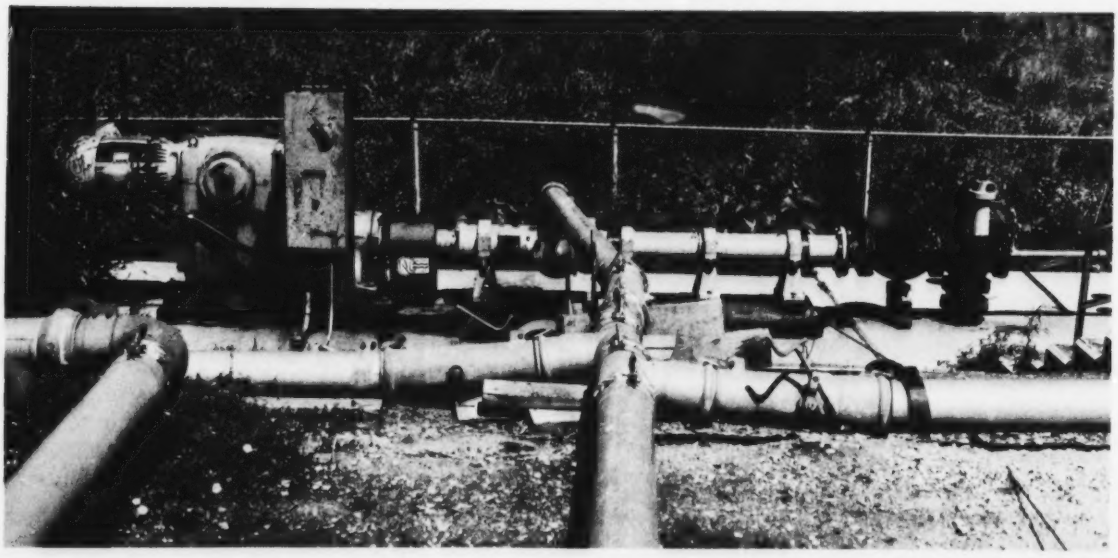

Figure 9. Fifty-horsepower booster pump.

Figure 10. Aluminum pipe connected to conveyance system under the railroad tracks.

While flooding with the gated irrigation pipe caused considerable ponding, the big disadvantage was that the gated pipe required frequent relocation to achieve uniform application. Because of the uneven terrain the liquid fertilizer often covered the gated pipe. This pipe was difficult to retrieve, empty, and clean before moving.

Flooding with a flexible hose proved the most practical method of application. While the liquid fertilizer still ponded because of the uneven terrain, placing the single discharge point on a high spot allowed the fertilizer to flow to lower portions of the terrain. Also, the flexible hose was easy to empty, clean and move. Repeating the process of applying two inches to three inches of liquid fertilizer, allowing it to dry, and disking to incorporate it into the soil, proved the most practical application method for this project.

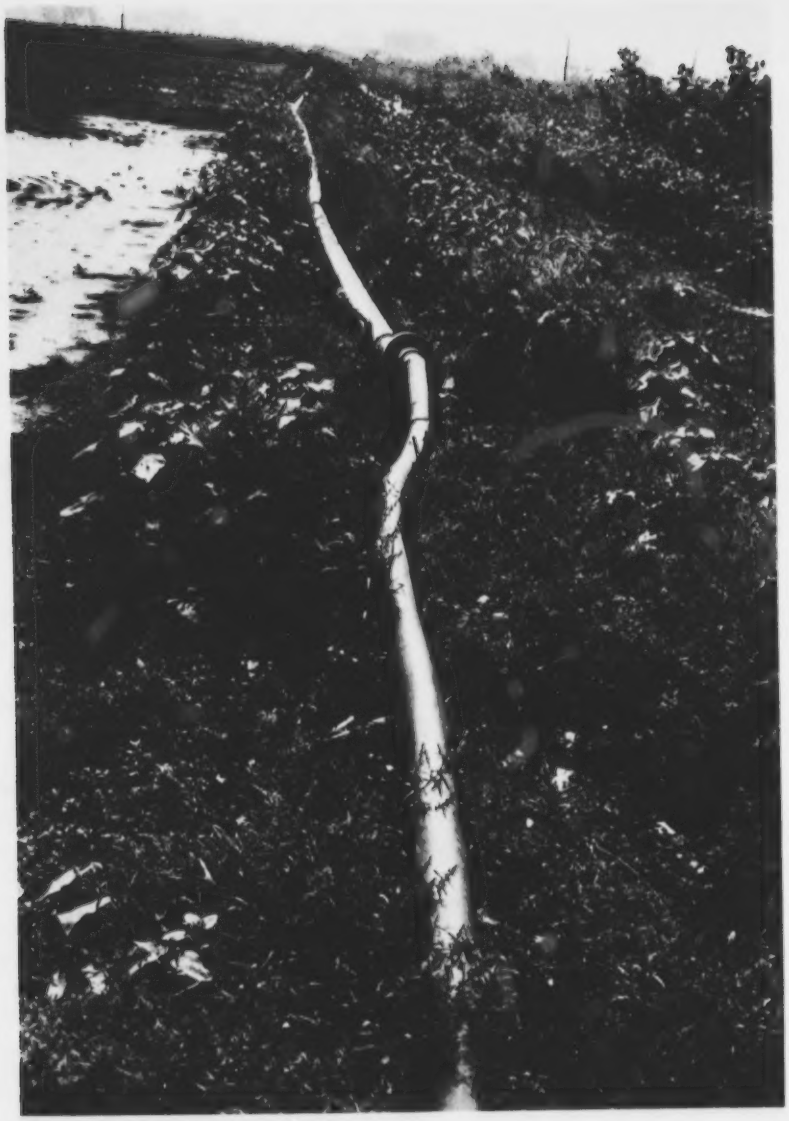

Figure 11. Aluminum pipe and vinyl hose.

SECTION 5

LIQUID FERTILIZER APPLICATION

During 1969, the liquid fertilizer application commenced on plots A thru E. Because the conveyance system from the Calumet plant and from the lagoons was not complete, trucks conveyed and applied the liquid fertilizer to the fields. Table 2 shows the plot designation, gallons applied, percent solids in the liquid fertilizer, total tons of dry solids applied and tons of solids applied per acre during 1969.

Table 2. LIQUID FERTILIZER APPLIED TO LAND AT THE CALUMET TREATMENT PLANT DUIRNG 1969

Plot	Gallons applied x 10^3	% Solids	Total dry tons applied	Plot size (acres)	Dry tons per acre
A	2694	3.06	344	5.0	68.8
B	276	3.48	40	4.93	8.1
C	1229	4.63	237	6.19	38.3
D	282	2.98	35	1.2	29.2
E	60	3.20	8	.90	8.9
	4541		664	18.22	36.4 T/A (avg.)

The total acreage was 18.22. The total gallons applied was 4,541,000. The average gallons per acre applied was 249,232. The total dry tons applied was 664. The average dry tons per acre applied was 36.4 The solids percent ranged from 2.98 to 4.63.

Difficulty in devising a system for removing fertilizer from the lagoon, and a trucking strike that delayed delivery of the irrigation pipe to the application site, delayed liquid fertilizer application to the plots on the north end (plots 1 through 20) of the farm until August 1 of 1970. 1970 was the first year that the fertilizer conveyance system was used from the digesters and the lagoons to convey liquid fertilizer to both the south and north ends of the application site. During June and July, the conveyance system did transport liquid fertilizer to the south end of the site. Table 3 shows the fertilizer applications for 1970.

TABLE 3. LIQUID FERTILIZER APPLICATIONS FOR 1970

Plot	Gallons applied x 10^3	% Solids	Total dry tons applied	Plot size (acres)	Dry tons per acre
A	1441	4.38	257	5.0	51.5
B	3954	3.30	544	4.93	110.5
C	1050	3.24	142	6.19	22.0
D	0		0	1.20	0.0
E	0		0	.90	0.0
F	0		0	1.22	0.0
1	0		0	1.55	0.0
2	0		0	1.55	0.0
3	0		0	1.55	0.0
4	0		0	1.55	0.0
5	153	6.27	40	1.55	25.8
6	252	4.38	46	1.55	29.6
7	0	4.38	0	1.55	0.0
8	400	4.37	73	1.55	47.0
9	225	3.73	35	1.55	22.6
10	4	1.18	2	.75	2.7
11	0		0	1.10	0.0
12	30	4.00	5	1.10	4.6
13	0		0	1.10	0.0
14	10	1.2	5	1.10	4.6
15	10	1.44	6	1.10	5.5
16	10	1.68	7	1.54	4.5
17	0		0	1.20	0.0
18	0		0	1.40	0.0
19	0		0	1.54	0.0
20	54	2.22	5	1.54	3.2
	7593		1167.0	46.86	39.6 T/A (avg.)

The total acreage was 46.86. However the acreage used for fertilizer application was 29.45. The total gallons applied was 7,593,000, for an average gallons per acre of 257,826. The total dry tons applied was 1167 and the average dry tons per acre applied was 39.6 The solids percent ranged from 1.18 to 6.27.

Table 4 shows this information for 1971.

TABLE 4. LIQUID FERTILIZER APPLICATIONS FOR 1971

Plot	Gallons applied x 10^3	% Solids	Total dry tons applied	Plot size (acres)	Dry tons per acre
A	2650	2.71	299.0	5.0	59.8
A	866	3.78	136.5	4.93	27.7
C	2588	2.59	287.6	6.19	45.0
D	443	2.36	43.4	1.20	36.2
E	302	2.31	29.0	.90	32.2
F	333	2.43	33.7	1.22	27.6
1	0		0.0	1.55	0.0
2	653	2.79	75.9	1.55	48.9
3	0		0.0	1.55	0.0
4	213	2.50	22.2	1.55	14.3
5	435	4.75	86.0	1.55	55.4
6	1020	4.44	188.3	1.55	121.5
7	1082	3.85	173.3	1.55	112.0
8	687	3.62	103.8	1.55	66.9
9	339	3.94	55.6	1.55	35.8
10	0		0.0	.75	0.0
11	112	4.54	18.9	1.10	17.2
12	0		0.0	1.10	0.0
13	0		0.0	1.10	0.0
14	263	2.50	27.4	1.10	24.9
15	0		0.0	1.10	0.0
16	539	3.07	69.0	1.54	44.8
17	226	2.98	28.1	1.20	23.4
18	945	2.68	105.7	1.40	75.5
19	390	2.36	38.4	1.54	24.9
20	97	2.23	9.0	1.54	5.9
	14183		1830.8	46.86	46.2 T/A (avg.)

The total acreage was 46.86. However, the total acreage used for liquid fertilizer application was 39.61. The total gallons applied was 14,173,000. The average gallons per acre applied was 357,814. The total dry tons applied was 1830.8 while the average dry tons per acre applied was 46.2. The solids percent ranged from 2.23 to 4.75.

Table 5 summarizes the liquid fertilizer applications for 1969, 1970 and 1971.

TABLE 5. LIQUID FERTILIZER APPLIED TO LAND AT THE CALUMET FARM DURING 1969, 1970, and 1971 (Dry tons)

Plot	Year applied 1969	1970	1971	Total
A	344	257	299.0	900.0
B	40	544	136.5	720.5
C	237	142	287.6	666.6
D	35	0	43.4	78.4
E	8	0	29.0	37.0
F		0	33.7	33.7
1		0	0.0	0.0
2		0	75.9	75.9
3		0	0.0	0.0
4		0	22.2	22.2
5		40	86.0	126.0
6		46	188.2	234.2
7		0	173.3	173.3
8		73	103.8	176.8
9		35	55.6	90.6
10		2	0.0	2.0
11		0	18.9	18.9
12		5	0.0	5.0
13		0	0.0	0.0
14		5	27.4	32.4
15		6	0.0	6.0
16		7	69.0	76.0
17		0	28.1	28.1
18		0	105.7	105.7
19		0	38.4	38.4
20		5	9.0	14.0
Total	664	1167.0	1830.8	3661.8
Dry Tons/Acre Applied	36.4	39.6	46.2	83.2

The total dry tons applied was 3,661.8; the total dry tons per acre applied was 83.2

During August of 1971, removal of all interior berms created just 5 plots, 3 on the north end and 2 on the south end. These plots and their approximate acreages are N1, 19; N2, 18; N3, 2; S1. 3; and S2, 20. Figure 4 shows this plot arrangement. The overall total was 62 acres, and was 15 acres more than used from 1969 thru 1971. The additional acres were the result of using plot N3, the triangular plot south of, but across the road from the check plot, and the roadways between plots A, B, and C. Plots 1 - 4 and 11 - 14 comprised N1, while plots 5 - 10 and 15 - 20 comprised N2. Plots D, E, and F comprised S1, while plots A, B, and C comprised S2.

The original intent for the 10 plots on the north end and 6 plots on the south end was to apply various loadings of liquid fertilizer on the plots and grow crops. However, the fly ash, which was the main constituent for the berms failed to retain the liquid fertilizer within each plot. To create berms capable of holding fertilizer would have required trucking in clay to provide material stable enough for berm construction. Reducing the number of plots from 26 to 5 eliminated 9212 feet of berms. Only the berms on the periphery of the 5 plots were repaired with clay. These berms are about 18 inches high.

Table 6 shows the fertilizer application for 1972.

TABLE 6. LIQUID FERTILIZER APPLICATIONS FOR 1972

Plot	Gallons applied x 10^3	% Solids	Total dry tons applied	Plot size (acres)	Dry tons per acre
N1	0		0	18.90	0.0
N2	3571	3.88	577	17.80	32.4
N3	478	2.17	43	1.75	24.6
S1	0		0	3.07	0.0
S2	2052	3.03	311	20.04	15.5
	6101		931	61.56	23.5 T/A (avg.)

The total acreage was 61.56 but the acreage used for application was 39.59. The total gallons applied was 6,101,000, while the average gallons per acre applied was 154,105. The total dry tons applied was 931 while the average dry tons per acre applied was 23.5. The solids percent ranged from 2.17 to 3.88.

During the 4 years, the total gallons applied to N1 was 1,281,00. The total dry ton equivalent applied was 154.4 which was 8.18 dry tons per acre. The total gallons applied to N2 was 9,353,000. The total dry ton equivalent applied was 1,472.9 which is 82.7 dry tons per acre. The total gallons applied to N3 was 478,000. The total dry ton equivalent applied was 43 or 24.6 dry tons per acre. The total gallons applied to S1 was 1,420,000, the total dry ton equivalent was 149 or 49.5 dry tons per acre. The total gallons applied to S2 was 18,800,00. The total dry ton equivalent was 2539.1 or 129 dry tons per acre.

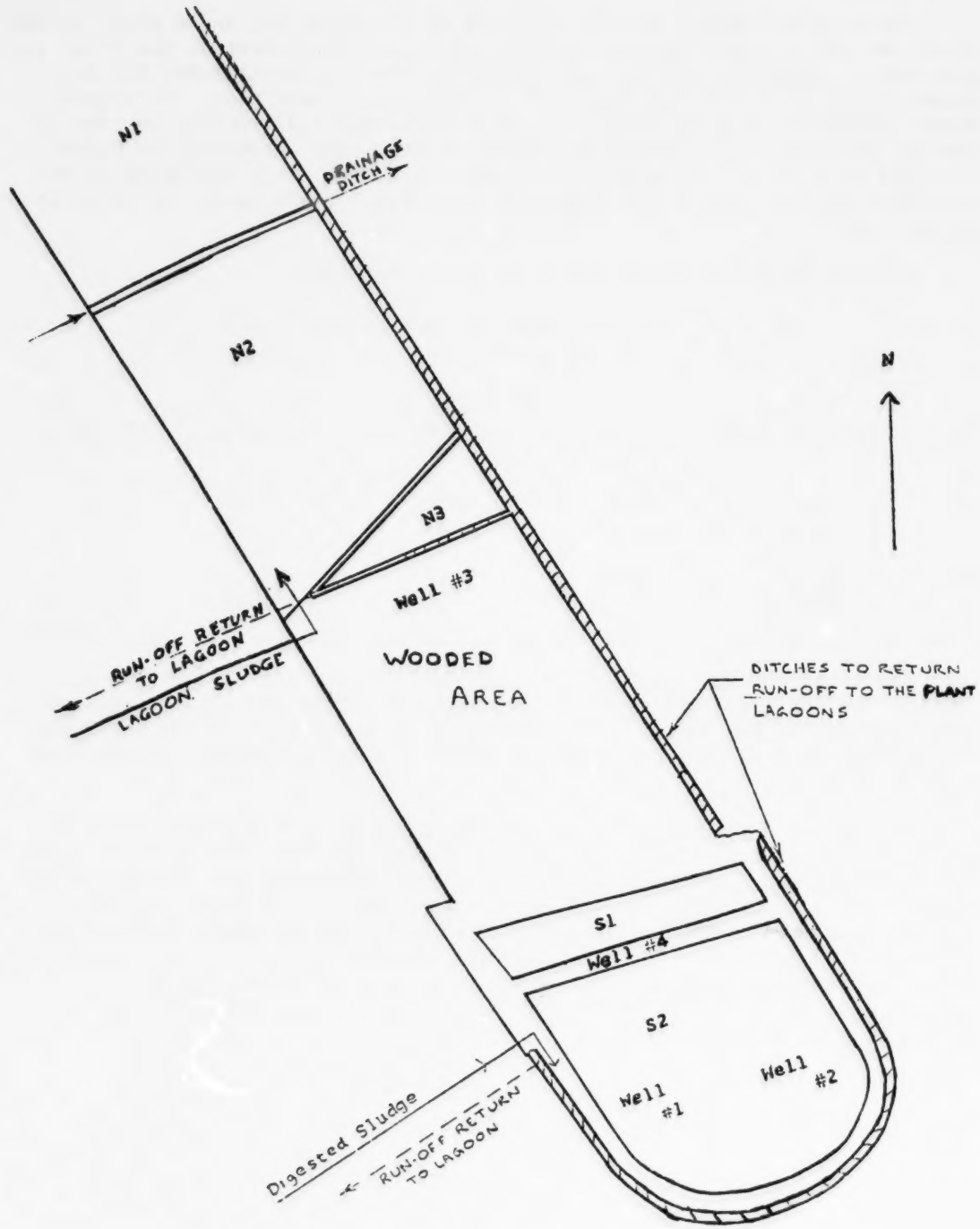

Figure 12. Calumet land reclamation site.

SECTION 6

CROP PRODUCTION

The planting of winter wheat during October of 1969, with a grain drill on plot A, followed the application of 68.8 dry tons per acre and incorporation of the liquid fertilizer into the soil with a disk. This wheat germinated and attained about six inches of growth before winter.

During the spring and summer of 1970, this wheat developed, matured, and yielded 42 bushels per acre as shown by harvesting 15 random samples. Figure 13 shows the method of wheat harvest. Plot A received an additional 51.5 dry tons of solids per acre as liquid fertilizer, after the wheat harvest in 1970.

Figure 13. Harvesting wheat for yeild determination.

During 1970, plot C and plots 11 through 20 grew corn. During 1969, plot C received 38.3 dry tons of solids per acre while during 1970 this plot received 22.9 dry tons solids per acre. Farming operations on plot C included debris removal, potash application (165 lbs. of K_2O per acre, as 275 lbs. per acre of muriate of potash, 0-0-60), plowing six inches deep, ridging and furrowing, corn planting, and spraying five pounds of herbicide per acre in 20 gallons of water. During corn planting, the planter also applied five pounds of soil insecticide per acre to control soil insects, particularly corn root worm. The corn was planted one inch deep in rows 40 inches apart. The planter planted 18,000 seeds per acre.

During October, the Purdue method (see appendix) for yield determination showed that plot C yielded 64 bushels of corn per acre.

Following the same farming operations, plots 11 thru 20 on the north end of the farm produced corn stalks. However, these plots received no liquid fertilizer, thus the corn failed to produce harvestable ears. Figure 14 shows corn treated with liquid fertilizer while Figure 15 shows corn not treated with liquid fertilizer.

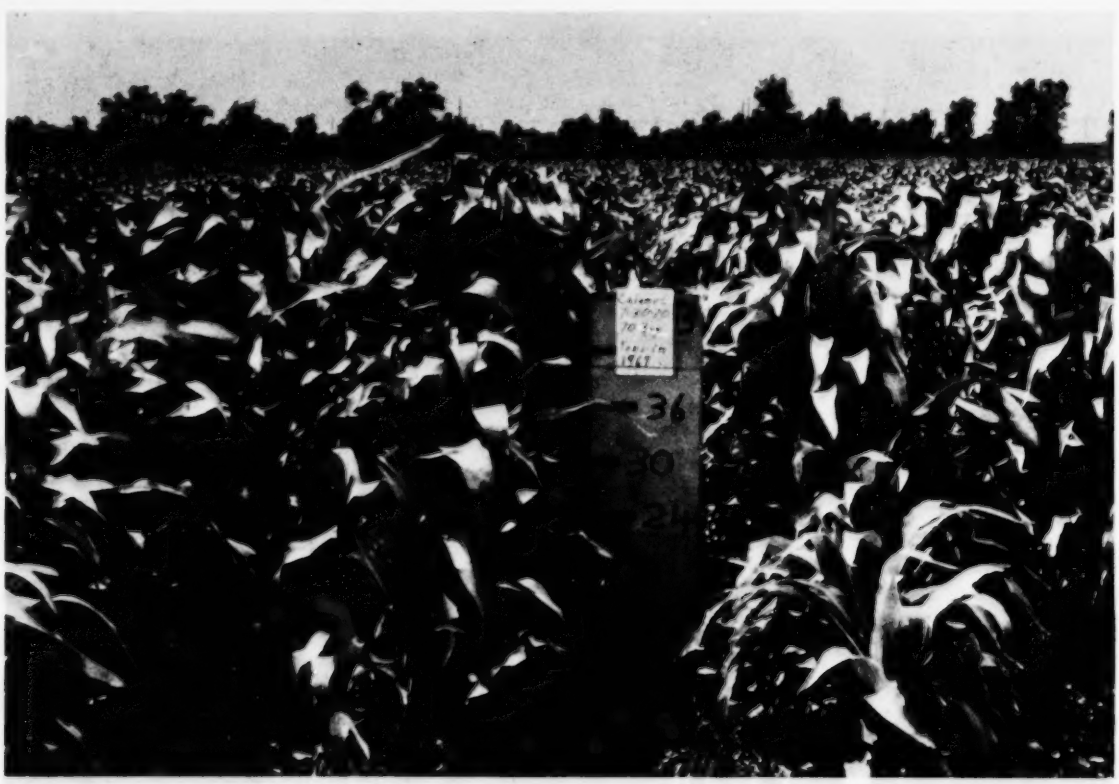

Figure 14. Corn fertilized with liquid fertilizer.

Figure 15. Corn not fertilized with liquid fertilizer.

In August of 1971, the interior berms were removed, forming the three plots on the north end and two plots on the south end of the farm. The three plots on the north end, designated N1, N2, and N3 contained 19, 18 and 2 acres, while the two plots on the south end, S1 and S2, contained 2 and 20 acres, respectively. Disking plots S1 and S2 to incorporate the solids with the soil preceded planting 75 pounds per acre of wheat during September 23 and 24. This wheat, a hard read winter variety, attained a height of 10 inches before frost. The appearance of this wheat looked excellent. These plots were not fertilized after seeding in 1971. Figure 16 shows the wheat.

Figure 16. Wheat fertilized with liquid fertilizer.

During 1972, this wheat attained a height of about 30 inches. Harvesting 15 random samples showed a wheat yield of 44 bushels per acre which was an average hard red winter wheat yield in Illinois in 1972. This wheat was not fertilized in 1972.

Debris in the soil matrix did not permit actual harvest of the crops. The debris caused numerous flat tires on the tractor while pulling the farm inplements. In addition, the debris, consisting of tires, iron bars, concrete test cores, pieces of concrete foundations, broken bottles, etc., hampered the use of the moldboard plow and the lister which formed the ridges and furrows. The debris also prevented the use of the rubble rake, the disk, and cultivator, and limited the ground speed of the corn planter, the sprayer, and the grain drill. The possibility of either the corn head, or a reel and sickle bar mounted on a combine, picking up small rocks, pieces of concrete, tires, glass, or iron bars also prevented harvest of the crop. Figure 17 shows the type of soil surface encountered.

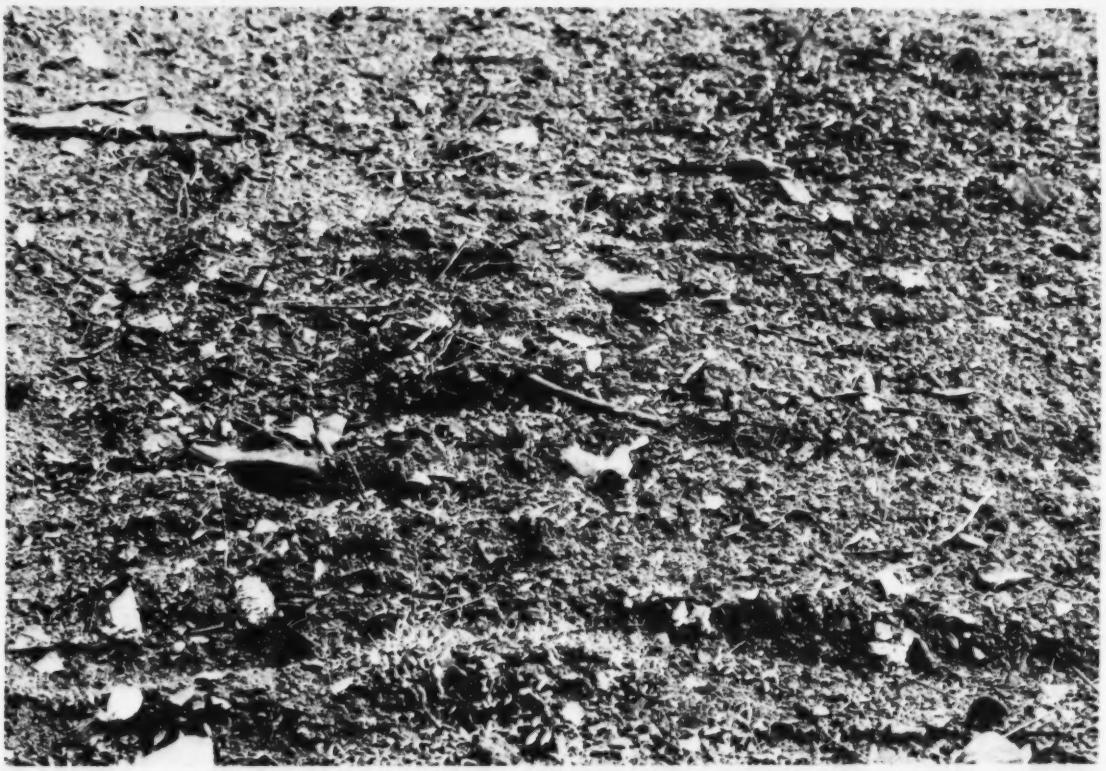

Figure 17. Soil surface, Calumet land reclamation.

SECTION 7

FARM EQUIPMENT USED ON THE CALUMET PROJECT

TRACTOR

The tractor used to pull the farm equipment was a 95-hp John Deere 4020 diesel four plow farm tractor (Figure 18) equipped with an Ansel Cab. The tractor performed satisfactorily. The only problem with using this tractor was that the debris caused numerous flat tires, sometimes two at a time. The reason Crawler tractors or tractors with steel wheels were not used was that the liquid fertilizer application site was more than a mile from the wastewater treatment plant and the only access was on hard surface public

Figure 18. Tractor used on the Calumet land reclamation project.

roads. The use of either crawler tractor or a tractor with steel wheels would have required hauling the tractor and the farm equipment each day. Because of vandalism, it was unsafe to leave equipment in the field overnite.

LANDSCAPE RAKE, MODEL 250

The John Deere Landscape rake proved too light to rake the debris into windrows for removal. It could not move larger debris and was constantly entangled with the iron bars protruding just slightly above the soil. Figure 19 shows the rake mounted on the tractor.

Figure 19. Landscape rake.

PLOW, MODEL F145H

The John Deere, 4-bottom, 16-inch plow failed to till the soil because of the incorporated debris. The plow bottoms tripped and folded back when they struck an obstruction. It was often necessary to reverse the direction of travel of the tractor and plow to reposition the bottoms. However, the moldboard plow rolling coulters were equipped with spring tensions so when the coulter struck an obstruction, it rolled over instead of breaking. Figure 20 shows the moldboard plow mounted on the tractor. Each moldboard was equipped with a trashboard attachment. The attachment was a projection

on the top and leading edge of the moldboard, and it's purpose was to increase the plow's effectiveness in covering trash. However, the trashboards failed to receive a fair test because of the soil debris.

Figure 20. Moldboard plow.

LISTER

The five lister bottoms, model SB-5A, mounted on a 96-inch real tool bar, model 23B, proved unsuccessful for ridging and furrowing because of the soil debris. Each lister bottom had shear bolts to prevent breakage. However, the shear bolts broke every few feet. The lister also came equipped with depth gauge wheels which prevented deep soil penetration. When functioning, the lister formed ridges and furrows on 40-inch centers. Figure 21 shows the lister.

CORN PLANTER

The John Deere corn planter consisted on four model 44 planter units on a tool bar. Each unit, operating independently, planted one row. This corn planter worked successfully in the debris-ridden soil because of the independence of each planting unit. This unit planted corn in rows 40 inches apart, the distance from the centers of the ridges formed by the lister.

Figure 21. Lister.

Planting the corn on the ridges instead of in the furrows allowed placement of liquid fertilizer in the furrows. In the recently tilled soil, the planting units easily shoved aside any debris in the path of the planter. The planter also contained soil inseticide applicators, a lift to aid the tractor hydraulic system to raise and lower the planting units, and a press tire to compact the soil. Figure 22 shows the corn planter.

SPRAYER

A John Deere Sprayer, model 32B, successfully sprayed herbicide on the weeds in the corn field during the early stages of crop growth. This sprayer had a 200-gallon capacity tank and sprayed a swath 24 feet wide. A pump operated by the tractor power takeoff provided the pressure for herbicide application. Figure 23 shows the sprayer. This sprayer also had, attached to the pump, a long hose and spray gun for spraying small patches of weeds within 30 feet of the sprayer.

Figure 22. Four-row corn planter.

Figure 23. Sprayer.

DISK HARROW

A 12-foot John Deere disk harrow, model BWF, proved to be too light for tilling this debris-ridden soil. Figure 24 shows this disk, equipped with blades 20 inches in diameter. The tractor's three-point hitch raised, lowered, and controlled the depth of tillage.

HEAVY DUTY DISK HARROW

This 11.5 foot model TWA John Deere heavy duty disk harrow, with notched blades 22 inches in diameter, was the most effective implement for tilling the debris-ridden soil. The heavy notched disk blades and the heavy frame did not bend or break during tilling operations. The depth of tilling was controlled by the hydraulic system. Figure 25 shows the disk.

BERM DISK

A model Tk34412K John Deere berm disk, successfully formed the berms for the plot borders. These berms 18 inches high, contained the liquid fertilizer within each plot. The three-point hitch and the hydraulic system on the tractor raised, lowered, and controlled the height of this berm disk, shown mounted on the tractor in Figure 26.

Figure 24. Twelve-foot disk harrow.

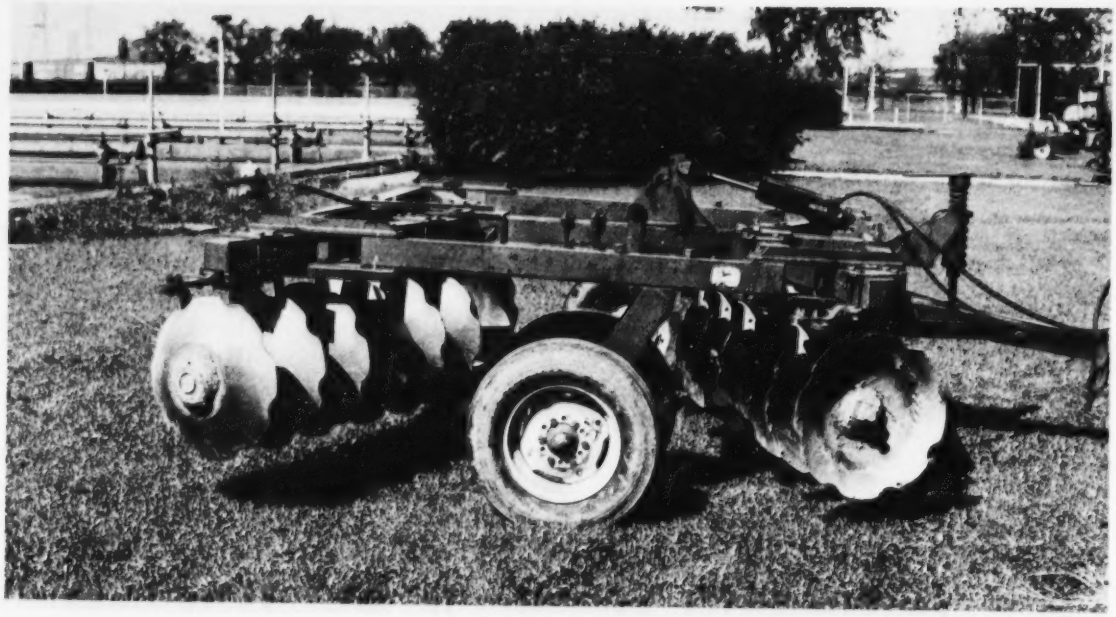

Figure 25. Heavy duty disk harrow.

Figure 26. Berm disk.

DITCHER

The John Deere ditcher, model E050M, successfully formed ditches for storm water drainage. The ditcher was used only around the periphery of the site. The three-point hitch and the hydraulic system on the tractor controlled the depth of operation of this ditcher, shown in Figure 27.

GRAIN DRILL

A John Deere, 11-foot grain drill, model B, successfully planted the winter wheat. Each furrow opener was spring loaded, allowing the necessary flexibility to roll over instead of breaking against the obstructions. Figure 28 shows this grain drill.

MOWERS

Two mowers were used. The John Deere Model 50 sickle bar mower cut the weeds on the periphery of the plots. The John Deere Gyromore Mower, equipped with a slip clutch and suction-type blades, cut the weeds when debris made it impractical to use the sickle bar mower. Figure 29 shows the sickle bar mower while Figure 30 shows the Gyromor.

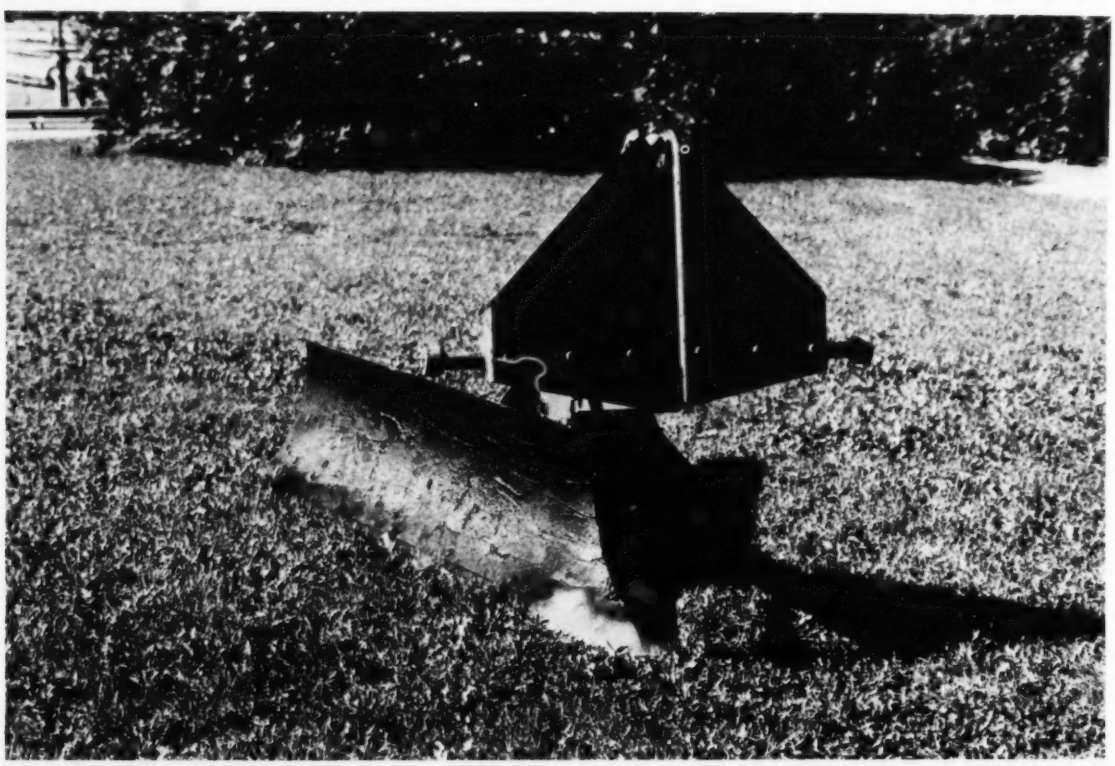

Figure 27. Ditcher.

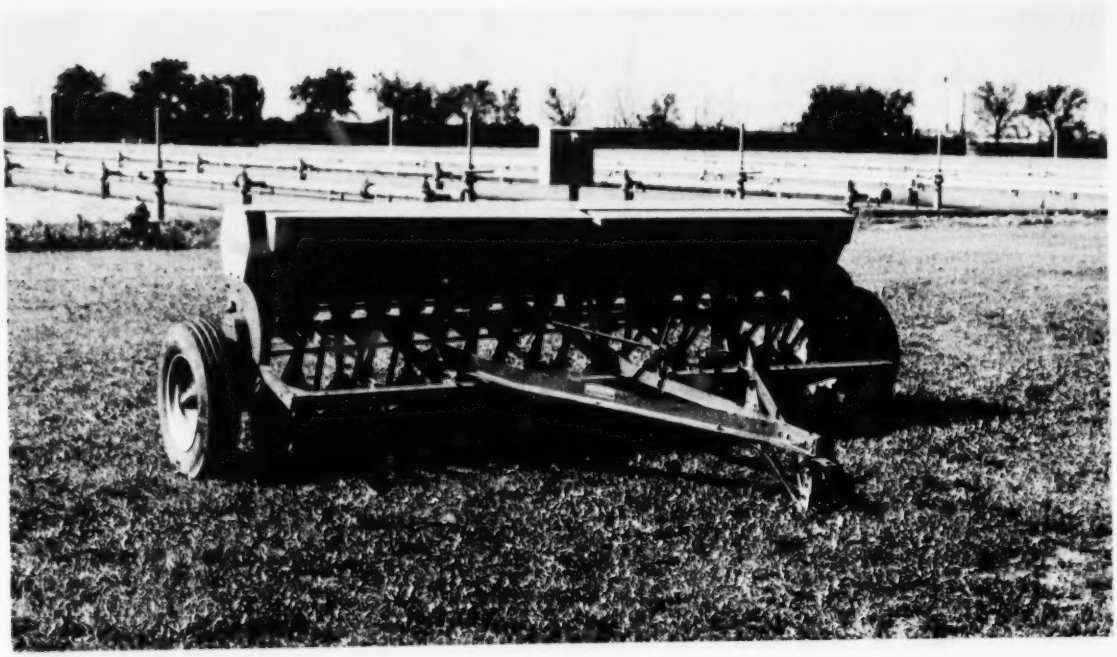

Figure 28. Grain drill.

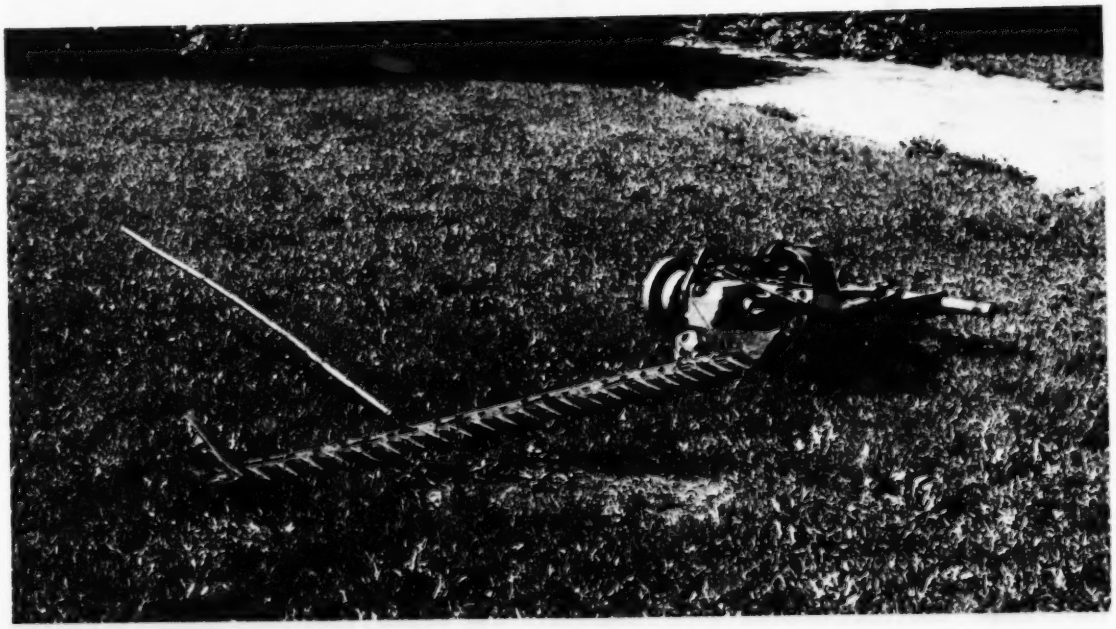

Figure 29. Sickle bar mower

Figure 30. Rotary Mower

Equipment purchased for the land reclamation project was as follows:

4020 tractor, diesel
Landscape rake
Plow, 4 bottom
Lister, 5 bottom
Corn planter, 4 row
Sprayer
Disk harrow, 12 foot
Disk harrow, 11.5 foot, heavy duty
Berm disk
Ditcher
Grain drill
Sickle bar mower

Equipment purchased but not shown in the report includes:

Tilt bed trailer
Land plane
Snowplow
Cultivator, 4 row
Disk harrow, 16.5 foot

The District purchased two complete sets of this equipment. One set was delivered to the Calumet plant while the other set was delivered to the West-Southwest Plant. One set of this equipment is still used at the Calumet farm while the other set is used on the Fulton County project.

SECTION 8

SOIL, PLANT, AND WATER RESPONSES

This report describes the effects of liquid fertilizer on a landfill east of the Calumet Sewage Treatment Plant for 1969 through 1972. Responses were noted for soil, groundwater, and plant tissues.

Soil samples were taken in February and May of 1969, in 1970, and 1972. Samples were composites of surface 6-inch plugs taken at random in Plot A (Figure 2). The 1969 soil samples were analyzed by a commercial laboratory. The other soil samples were crushed to pass a 2-mm sieve and analyzed by MSD laboratory for the following constituents: pH (Peech, 1965) and electrical conductivity (Bower and Wilcox, 1965) measured using a 1:1 soil to water ratio; available P (Olsen and Dean, 1965): total Kjeldahl nitrogen (Bremmer, 1965a); NO_2 + NO_3 - N and exchangeable NH_4 - N (Bremmer, 1965a); organic carbon, determined by Walkley-Black titration (Allison, 1965); cation exchange capacity (CEC), measured by ammonium acetate-sodium chloride method (Chapman, 1965); exchangeable Ca, Mg, K, Na, determined by atomic absorption analysis of ammonium acetate extract used in CEC determination (Chapman, 1965); 0.1N HCl extractable Zn, Mn, Cu, Ni, Pb, Cr, and Cd, analysis by atomic absorption; total sulfur by Leco induction furnace; and field moisture capacity by 1/3 bar pressure plate extraction (Peters, 1965).

Accumulative liquid fertilizer application were shown in Tables 5 and 6, and the annual mean analysis of liquid fertilizer applied in 1969 through 1972 is reported in Table 7. Analysis of the soil samples is shown in Table 8. The addition of liquid fertilizer to landfill soil resulted in increases in the soil of available phosphorus; cation exchange capacity (CEC); exchangeable Ca, Mg, K: and 0.1N HCl extractable Zn, Mn, Cu, and Pb. Decreases were noted for Ni, Cr, exchangeable Na, and exchangeable Al. Most of these changes were agronomically beneficial.

At the May 1970 soil sampling winter wheat tissue samples were also collected. Visually, at sampling the south half of the field had better growth than the north half, so composite samples of the above ground portion of plants in the boot stage of development from the north and south sections were taken. Chemical analysis of north and south plant composites is shown in Table 9. These data showed that wheat tissue from the north section of the field generally contained lower concentrations of the 14 elements determined than wheat tissue from the south section of the field. The availability of essential plant nutrients appeared adquate. However, the zinc concentration was regarded as higher than that required for maximum crop production but not at a toxic level. There was no crop in 1971.

TABLE 7. ANALYSIS OF LIQUID FERTILIZER APPLIED AT CALUMET FARM FROM 1969 to 1972 (lb/dry ton)

Date*	1969	1970	1971	1972
Total Solids	2000	2000	2000	2000
Tot. Vol. Sol.	932	950	1045	1026
Total P	55	32	80	59
N-Kjeldahl	103	74	90	85
$N\text{-}NH_3$	46	19	38	24
Alk. as $CaCO_3$	N.A.*	75	146	132
Fe	88	81	72	69
Zn	7.9	7.6	7.2	6.2
Cu	2.1	2.3	2.3	1.5
Ni	0.3	0.4	0.5	0.9
MN	2.7	N.A.	N.A.	0.8
K	11.0	1.6	N.A.	5.8
Na	N.A.	3.9	N.A.	10.1
Mg	12	17	N.A.	23
Ca	84	56	N.A.	79
Pb	4.8	4.2	2.4	2.4
Cr	3.3	3.2	1.5	3.5
Cd	0.2	0.3	0.3	0.4
Al	N.A.	18	23	21
Hg	N.A.	.0125	0.006	0.006

*N.A. - No analysis

Groundwater leachate samples were collected weekly from three piezometers (Figure 2) for three and one half years. The piezometers, approximately twenty feet deep, are made of perforated stainless steel pipe and screened at the bottom. Chemical analysis and fecal coliform (FC) density were conducted on all samples. Tables 10, 11, 12, and 13 show the annual mean of 23 chemical constituents and the geometric mean of FC density for each of the piezometers from May 1969 through June 1972.

Table 13 shows the mean chemical concentrations of the groundwater leachate for the first six months of 1972 from the three piezometers and one monitoring well. The monitoring well was drilled into the strata underlying the landfill material. This well is 130 feet deep, with a screen on the last 10 feet, and monitors leachate percolating into the nearest natural aquifer. Figure 31 shows the well and Figure 32 is a schematic of the well construction.

In 1969 only plots A through E (Figure 1) were fertilized. Therefore, piezometers 1 and 2 were in the liquid fertilizer treated area and piezometer 3 was approximately 1000 feet from the liquid fertilizer treated area.

TABLE 8. SUMMARY OF SOIL CHARACTERISTICS (0-6" DEPTH) OF PLOT A, CALUMET FARM, BEFORE AND THREE DATES AFTER THE APPLICATION OF LIQUID FERTILIZER

Characteristic	Unit	Sampling data			
		2-69	5-69	5-70	5-72
pH		7.5	7.6	7.5	6.7
p-Total	ppm	-	70.	-	-
p-Avail.	ppm	12.	47	22.	-
N-Kjeldahl	ppm	-	4283	-	-
$N\text{-}NO_2+NO_3$	ppm	-	11	-	-
Organic Carbon	%	-	7	8.6	-
CEC meg/100 g		-	11.	20.4	35.1
Exchangeable	ppm				
Ca	-	2450	1783	6115	3673
Mg	-	150	209	565	550
K	-	90	153	178	205.
Na	-	560	217	295	204.
NH_4-N	-	-	1420	-	-
AL	-	46	30	2.5	-
Zn	ppm	575	71	1807	2683
Mn	ppm	46	79	370	335.
Cu	ppm	82	50	383	476
Ni	ppm	100-200	123	50	43.7
Pb	ppm	-	123	450	465.
Cr	ppm	-	321	14	56.4
Cd	ppm	-	72	34	71.9
S-Total	ppm	-	-	4198	4274
$B\text{-}H_2O$ soluble	ppm	-	4.5	-	-
E.C.	mmhos/cm	3.2	1.4	2.4	1.12
Bulk density	g/cc	-	0.9	-	-
Field moisture capacity	%	34	42.	-	43.7

In 1970, water samples were collected weekly from September through December. Mean chemical concentrations (Table II), except $NO_2 + NO_3$ - N for piezometer 1 leachate, were lower in 1970 than in 1969. The leachate from piezometer 2 had higher average Kjeldahl-, NO_3-, and $NO_2 + NO_3$ - N concentrations and a general decrease in heavy metal concentration in 1970 compared to 1969.

In 1971, leachate chemical concentration of piezometer 1 showed increases in P, NH_3 - N, $NO_2 + NO_3$ - N, Mn, Cr, Cd, and Fe compared to 1970. This may be in part due to the lack of a growing crop in 1971 on Plot A.

The yearly summary of chemical concentration in the groundwater leachate is presented in Table 14. The general trends show annual increases Kjeldahl-, NO_3-, and $NO_2 + NO_3$ - N and decreases in P, SO_4, electrical conductivity, Zn, and Na.

That these piezometers were constructed of perforated pipe their full length, from the soil surface downward, was the cause of much of the pollution in the leachate taken from them. During rainfall or liquid fertilizer application, water containing solids entered the perforated pipe polluting the water in the piezometer.

To determine if this pollution reached the groundwater aquifer a deep well was constructed of solid wall pipe to within ten feet of the bottom of the well. Also this well has a concrete slab, four feet square, surrounding the top of the well. Table 13 shows that, with the exception of N, Na, Cr, and Al, the water from this monitoring well contained lower concentrations of all the parameters tested than the groundwater leachate from the piezometers.

TABLE 9. CHEMICAL CONTENT OF WINTER WHEAT TISSUE* FROM A LIQUID-FERTILIZER-TREATED LANDFILL AT THE CALUMET FARM† (µg/g, OVEN DRY BASIS)

Element	Sampling Site	
	North half	South half
N-Kjeldahl	19200	23800
P	3900	4198
Ca	4011	5520
Mg	1719	1694
K	28914	39080
Na	260	301
Zn	61.71	81.99
Fe	114.6	147.6
Mn	28.2	67.8
Cu	5.73	9.84
Ni	0.44	0.00
Pb	6.17	10.38
Cr	6.61	7.65
Cd	0.44	0.55

*The plants were sampled at the boot stage of development.
†Collected May 28, 1970

TABLE 10. CALUMET LAND RECLAMATION SITE MEAN CHEMICAL CONCENTRATIONS (PPM) FOR LEACHATE COLLECTED MONTHLY FROM THREE PIEZOMETERS DURING MAY THROUGH DECEMBER, 1969 (mg/1)

Constituent	Piezometer* (pH 6.2-7.1)	(pH 6.5-7.4)	(pH 6.3-6.9)
Total P	1.2	6.9	0.8
Cl	1790	2767	160
SO_4	3224	2254	1070
N-Kjeldahl	9.8	33.8	13.6
N-Organic	3.2	7.8	1.7
N-NH	6.7	26.0	11.9
$N\text{-}NO_2 + NO_3$	0.67	0.16	0.15
Alkalinity as $CaCO_3$	577	1477	345
Conductivity umhos/cm	10,106	16,500	2,931
Zn	514	64.12	297
Cu	0.48	0.85	0.21
Ni	0.03	0.17	0.004
Mn	1.06	6.58	0.68
Mg	279.7	369.0	123.9
K	52.6	145.7	55.73
Na	1473	1434.6	103.04
Ca	401	566.3	258.8
Pb	0.77	2.68	0.43
Cr	0.03	0.08	0.00
Cd	0.02	0.02	0.00
Fe	21.99	62.87	12.49
FC/100 ml (geometric mean)	10	13	10

*Piezometers 1 and 2 were located in the liquid-fertilizer-treated areas; piezometer 3 was not.

TABLE 11. CALUMET SANITARY LANDFILL SITE MEAN CHEMICAL CONCENTRATIONS FOR LEACHATE COLLECTED WEEKLY FROM THREE PIEZOMETERS FROM SEPTEMBER THROUGH DECEMBER 1970 (mg/1)

Constituent	Piezometer (pH 6.7-8.2)	(pH 6.9-8.4)	(pH 6.8-8.1)
Total P	0.35	5.26	1.44
Cl^-	95.4	464	363.9
SO_4	821.4	1064	1496.5
N-Kjeldahl	6.22	104.6	24.5
N-Organic	2.25	5.2	7.0
$N\text{-}NH_3$	3.97	99.4	17.5
$N\text{-}NO_2 + NO_3$	0.68	6.7	2.05
Alkalinity as $CaCO_3$	438.1	863	933.1
Conductivity umhos/cm	3641.1	3882	2114.2
Zn	56.1	22.2	18.1
Cu	0.28	0.182	0.127
Ni	0.046	0.096	0.09
Mn	0.76	1.42	2.64
Mg	88.9	120	153.6
K	32.5	60.5	56.8
Na	243.2	758	854.3
Ca	291.3	289.5	443.1
Pb	0.526	0.376	0.426
Cr	0.005	0.018	0.006
Cd	0.006	0.038	0.019
Fe	21.7	36.4	44.9
Hg ug/l (4 samples)	1.25	1.85	1.55
FC/100 ml (geometric mean)*	15	102	90

* Fecal Coliform determined weekly from January through December 1970.

TABLE 12. CALUMET SANITARY LANDFILL SITE MEAN CHEMICAL CONCENTRATION FOR LEACHATE COLLECTED WEEKLY FROM THREE PIEZOMETERS FOR THE YEAR 1971 (mg/l)

Constituent	Piezometer (pH 6.5-7.8)	(pH 6.8-8.8)	(pH 6.8-7.8)
Total P	1.1	2.3	1.0
Cl^-	82	714	404
SO_4	537	747	885
N-Kjeldahl	7.8	132.3	38.6
N-Organic	1.7	25.5	8.0
$N\text{-}NH_2$	6.1	93.5	30.6
$N\text{-}NO_2 + NO_3$	4.38	11.2	14.7
Alkalinity as $CaCO_3$	111	850	845
Conductivity umhos/cm	1150	4225	3914
Zn	26.2	27.3	18.0
Cu	0.23	0.26	0.23
Ni	0.06	0.09	0.17
Mn	2.30	0.92	2.07
Mg	93.8	180.5	190.2
K	33.1	57.1	64.3
Na	74.8	668.9	541.0
Ca	294.4	280.8	438.0
Pb	0.43	0.45	0.75
Cr	0.4	0.04	0.04
Cd	0.01	0.02	0.04
Fe	57.5	53.4	80.1
Al	6.1	5.1	4.9
Hg ug/l (4 samples)	1.69	1.40	2.02
FC/100 ml (geometric mean)	19	266	106

TABLE 13. CALUMET SANITARY LANDFILL SITE MEAN CHEMICAL CONCENTRATIONS FOR LEACHATE COLLECTED MONTHLY FROM JANUARY 25, 1971 TO JUNE 23, 1972, FROM THREE PIEZOMETERS AND A MONITORING WELL (mg/l)

Constituent	Piezometer 1 (pH 7.2-7.7)	Piezometer 2 (pH 7.9-8.3)	Piezometer 3 (pH 6.6-7.5)	Well 4* (pH 8.5-9.8)
Total P	0.69	0.59	0.45	0.39
Cl^-	60	881	255	50
SO_4	451	619	532	29
N-Kjeldahl	3.0	44.8	7.1	0.9
$N\text{-}NH_3$	1.9	39.6	4.1	0.7
$N\text{-}NO_2 + NO_3$	1.49	1.63	2.15	0.07
Alkalinity as $CaCO_3$	760	1143	765	808
Conductivity, umhos/cm	2250	4300	2087	568
Zn	42.1	15.7	35	0.04
Cu	0.24	0.14	0.15	0.03
Ni	0.01	0.04	0.2	0.04
Mn	0.42	0.33	1.75	0.09
Mg	102	351	92	4
K	20.5	47.9	24.6	3.3
Na	54	1001	249	136
Ca	262.1	79.4	376	6.0
Pb	0.69	0.37	0.36	0.04
Cr	0.01	0.01	0.02	0.01
Cd	0.01	0.02	0.01	0.002
Fe	90.6	38.1	76.5	2.9
Al	4.2	3.8	1.1	5.4
Hg, ug/l	2.1	0.6	0.7	0.4
FC/100 ml (geometric mean)	31	20	28	N.A

*New well.

TABLE 14. CALUMET SANITARY LANDFILL SITE ANNUAL MEAN CHEMICAL CONCENTRATIONS FOR LEACHATE FROM 1969 TO 1971 (mg/l)

Constituent	Yearly average of 3 piezometers 1969	1970	1971
Total P	3.0	2.4	1.46
Cl	1572	364.0	400
SO_4	2182	1127.3	723
N-Kjeldahl	19.0	45.10	59.5
N-Organic	4.2	4.81	11.7
$N\text{-}NH_3$	14.8	40.29	43.4
$N\text{-}NO_2 + NO_3$	0.32	3.14	10.9
Alkalinity as $CaCO_3$	799	744.7	602
E. C. umhos/cm	9845	3879.1	3096
Zn	308.8	32.1	23.8
Cu	0.51	0.299	0.24
Ni	0.068	0.077	0.11
Mn	2.77	1.60	1.76
Mg	257.5	120.8	154.8
K	84.60	49.9	41.57
Na	1547.2	618.5	428.2
Ca	408.7	341.3	337.7
Pb	1.35	0.442	0.54
Cr	0.04	0.010	0.16
Cd	0.01	0.021	0.02
Fe	32.4	34.3	63.6
Hg, µg/l	-	1.55	1.70
Al	-	-	5.3

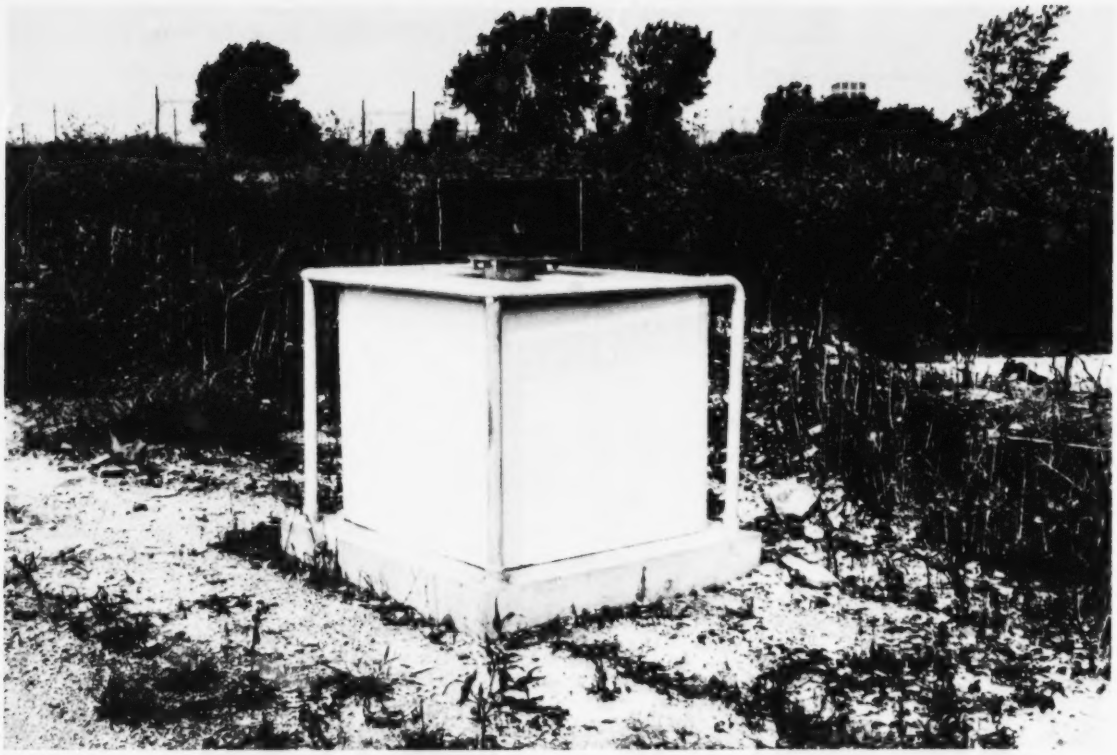

Figure 31. Monitoring Well, Calumet Farm.

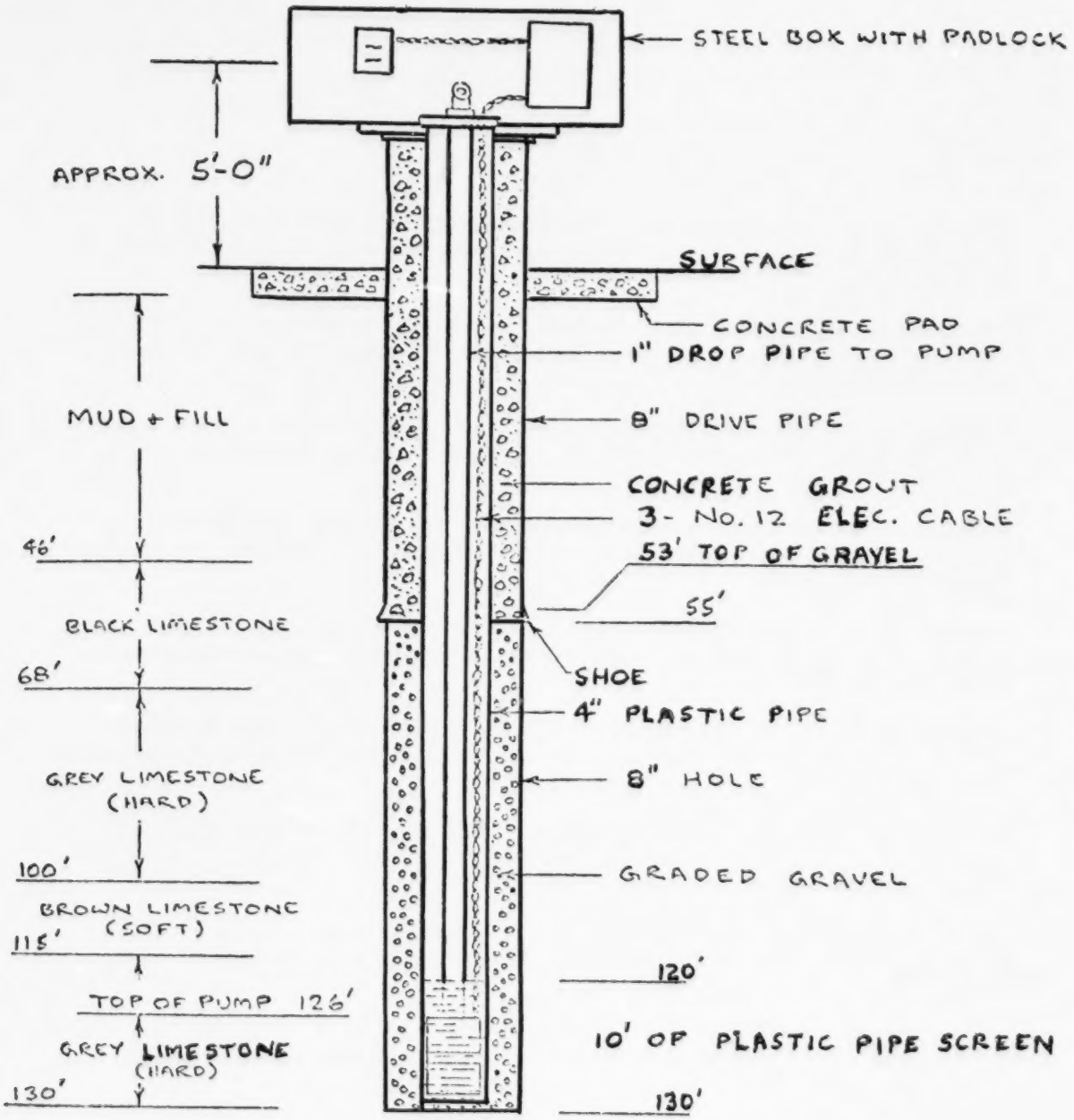

Figure 32. Drawing of Monitoring Well, Calumet Farm

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